SENSOR FOR MEASURING A GAS CONCENTRATION OF ION CONCENTRATION

This invention relates to a sensor for measuring a gas concentration or ion concentration according to the preamble of Claim 1.

Such a sensor is known from DE 101 18 367 A1, which originated with the applicant.

Sensors with field-effect transistors (FETs) for measuring gas concentrations, which use as the gate a gas-sensitive layer whose work function depends on an ambient gas concentration, are known for example from US 4,411,741.

Sensors with field-effect transistors using as the gate an ion-sensitive layer whose potential depends on the ionic concentration of an ambient liquid or an ambient gas are among the known sensors for measuring ion concentrations. US 5,911,873 discloses one such ion-sensitive FET (ISFET).

Such sensors are generally fabricated by counter-doping a semiconductor substrate so as to generate in it a drain and a source and growing or depositing an insulating layer on the substrate between the source and the drain. An ion-sensitive layer can be applied directly onto this insulating layer. A gas-sensitive layer can be made a certain distance away; this is called a suspended-gate FET (SGFET). Alternatively, a gate can be applied to the insulator and controlled capacitively by a gas-sensitive gate made a certain distance away. Such a sensor, called a capacitively controlled FET (CCFET), is described for example in DE 43 33 875 C2.

A disadvantage of these configurations is that after a certain time, surface conductivity that is always present pulls the potential over the FET to the potential that is present on the gas-sensitive gate, causing the drain-source current to drift. To prevent this, a conductive ring, also called a guard ring, which can be set to a well-defined potential, is conventionally laid around the FET. In such a configuration, the channel region of the FET takes on the potential of the guard ring after a certain time because of the surface conductivity of the region between the guard ring and the channel region. The distance between the guard ring and the channel region of the FET and the conductivity of the surface define the time required for the channel region to take on the guard ring potential, thus establishing the minimum possible concentration change per unit time that a gas signal for detection may have in order to be registered. This distance governs the size and hence also the manufacturing costs of such a sensor.

The goal of the invention is to create a further sensor that can be manufactured at low

cost, has small dimensions, and nevertheless guarantees a high accuracy of measurement for the change in concentration as a function of time. In particular, the surface resistance between the guard ring and the FET is to be made higher, so that the minimum rise in concentration per unit time for a detectable gas signal is increased.

This goal is achieved with a sensor according to Claim 1.

The dependent claims describe preferred developments.

Thus, according to the invention, the surface conductivity between the guard ring and the FET is increased in a surprisingly simple way without it being necessary to make the circuit larger in size. The invention provides for arranging around the FET structures, preferably rings, that are defined by a surface material different from the remaining surface material and thus having different surface conductivities and being able to form contact resistances. Additionally, surface profiling according to DE 101 18 367 A1 can further be provided in order to increase further the RC time that describes the equalization of the FET potential to the potential of the guard ring without impairment of the functionality of the sensor configuration by this surface profiling. Such surface profiling additionally further lengthens the RC time. With the use of surface profiling, the raised regions are to have a surface conductivity different from, preferably smaller than, the lowered regions.

According to the invention, surface profiling can be fashioned in a simple way by additionally fashioning, on a previously generated thick oxide layer, elevations spaced some distance apart.

According to the invention, the preferably annual structures arranged on the thick oxide layer and defined by a surface material different from the remaining surface material have different surface conductivities and therefore form different, preferably higher, contact resistances. The overall effect of the invention is to increase the surface resistance between the guard ring and the FET so that the minimum concentration rise per unit time of a gas signal is increased.

The fashioning even of larger elevations in the air gap between the sensitive gate layer and the thin oxide layer above the channel region does not present any problems as a rule.

In what follows, some embodiments of the invention are explained in greater detail on the basis of the drawings, in which:

Figure 1 is a top view of a sensor according to one embodiment of the invention;

Figure 2 is a section along line A-A' in Figure 1;

Figure 3 is a section similar to that in Figure 2 but through a different sensor;

Figure 4 is a top view of a second exemplary embodiment of a sensor according to the invention.

On a substrate 11 of a first charge-carrier type, for example made of n-doped silicon, a gas sensor has a source 2 and a drain 3 of a second charge-carrier type, for example made of p-doped silicon, which are fashioned, for example, by ion implantation.

Source 2 has a source terminal 6 and drain 3 has a drain terminal 5. In the substrate between source 2 and drain 3 there is a channel region 4, on which a thin oxide layer 13 is fashioned. Insulator layers, for example thick oxide layers 14, are fashioned on source 2 and drain 3, a guard ring 1 made of a conductive material being applied onto their surfaces, which guard ring, as shown in the top view of Figure 1, runs around channel region 4 and can be set to a well-defined potential.

Arranged on lateral insulator regions 9 is a gas-sensitive gate layer 8 whose potential depends on an ambient gas concentration. An air gap 10 is fashioned between gate layer 8 and thin oxide layer 13. Thin oxide layer 13 can be for example 3-50 mm thick and acts, together with the air gap, as a gate dielectric. Changes in the gas concentration can thus be detected as changes in the source-drain current.

Between thin oxide layer 13 above channel region 4 and guard ring 1 there is a special surface structure by which the surface resistance between guard ring 1 and the FET is increased. Through suitable layer deposition steps and the use of photomasks as well as subsequent etching, well-defined materials, for example in the form of one or a plurality of ring structures, are arranged on thick oxide layer 14 or embedded therein. These ring structures are identified by reference character 12[1] in Figure 1 and Figure 2. The ring structures can be fashioned as circular rings or, as shown in Figure 1, as quadrilaterals or also polygons. Aluminum or aluminum with a copper content is a candidate material for the ring structures, so that ring structures 12 form an aluminum oxide on their surface upon exposure to ambient air. This has the effect that the resistance on the surface between guard ring 1 and channel 4 is increased, so that the RC time required for equalization of the FET potential to the guard ring potential is prolonged.

[1] The reference characters in the translation follow those in the text of the original specification, not those used in the Drawings—Translator.

Figure 3 shows a sensor similar to the one in Figure 2. There, however, ring structures 12 rise above the rest of the surface of thick oxide layer 14 in the direction toward air gap 10. The regions lying between this elevation 12, that is, raised ring structures 20, are identified as depressions 12. Raised ring structures 20 have a surface conductivity lower than that of depressions 12. The fashioning of elevations 7 and depressions 12 leads to surface profiling of thick oxide layer 14. The profiling of surface 15 can in particular be fashioned by the application of layers on thick oxide layer 14 through appropriate deposition steps followed by etching steps defined by photomasks to uncover the depressions. Elevations 7 applied by deposition are made of a material different from thick oxide layer 14. A material with a low surface conductivity, such as aluminum or aluminum with a copper content, is used for surface profiling. Upon contact with air, this forms an aluminum oxide on the surface, so that the surface conductivity is markedly lowered. Thick oxide layer 14 is uncovered where the layers were etched, that is, in depressions 12.

It is additionally pointed out that thin oxide layer 13 can also be implemented as a capacitance. For purposes of disclosure in this connection, reference is made to the complete content of the patent application titled "Sensor for Measuring an Ion Concentration or Gas Concentration," filed with the German Patent and Trademark Office by the same applicant on the same date as the present application.

A second embodiment of the invention is shown in Figure 3. In this exemplary embodiment, the field-effect transistor formed from source 2 and drain 3 is spatially separated from air gap 10 between gate layer 8 and channel region 4. Gate 12 of the field-effect transistor is here led in insulated fashion via an electrode 19 below elevations 7 into channel region 4 below air gap 10.